ABSTRACT

The present study is focussed on analysing the formability and associated deformation behaviour of AA8090 Al-Li alloy sheet at ambient temperature employing out-of-plane stretch forming and single point incremental forming (SPIF) tests. Further, tensile tests have been conducted at elevated temperatures to comprehend the hot deformation characteristics of the AA8090 sheet. A detailed microstructural and microtextural evolution following different processes have been studied using electron back scatter diffraction (EBSD) technique. The visco-plastic self-consistent (VPSC) simulation has been conducted to predict the texture evolution and gain insights into the underlying deformation behaviour during different processes. Using out-of-plane stretch forming test, a series of strain paths ranging from tension-compression to tension-tension regions are attained. The maximum effective plastic strain is induced in the specimen deformed along equi-biaxial mode of deformation, i.e., EBD specimen. Consequently, a higher fraction of sub-grain boundaries (SGBs) and deformed grains are formed in EBD specimen, followed by uniaxially deformed (UD) and plane strain deformed (PSD) specimens, respectively. In uniaxial mode of deformation, there is a relative strengthening of Cube texture {001}<100> as compared to as-received (AR) specimen. On the contrary, Cube texture is weakened during plane strain and equi-biaxial modes of deformation. The VPSC predicted texture using monotonic velocity gradient corroborates well with the experimental counterparts. The simulation demonstrated that average number of active slip systems increased with strengthening of Cube texture during uniaxial deformation. Further, the Taylor factor analysis has been conducted which depicts the presence of higher fraction of grains in Taylor factor range M ~ 3-4 in EBD specimen as compared to UD and PSD specimens. The PSD specimen also has appreciable number of grains having very high Taylor factor M ~ 4-5 which could be attributed to the premature failure of the specimen at lower strain. During SPIF process, it is observed that effective plastic strain induced in SPIF deformed geometries is significantly higher in comparison to stretch formed geometries. To elucidate the mechanism responsible for higher formability during SPIF process, a multiscale finite element (FE) coupled VPSC simulation has been conducted. Towards this, the strain distribution in SPIF fabricated geometries is analysed using FE simulation. The six strain components (normal and shear) have been incorporated into the VPSC model to design the variable velocity gradient, and predict the texture evolution. It is observed that the texture predicted using variable velocity gradients (considering shear components) is in good agreement with the experimental ones, unlike the texture simulated employing monotonic velocity gradient (i.e., excluding shear components). The VPSC simulation demonstrated that the presence of shear components deviates the rotation path of orientations from developing stable texture components, resulting in spread of orientation. Hence, it can be presumed that the evolution of shear strains reduces the sharpness of texture which could be attributed to higher formability during SPIF process.

During elevated temperature tensile tests, it is observed that AA8090 alloy exhibits moderate elongation and significant softening following deformation at 673 K. Contrarily, the alloy experiences exceedingly higher elongation with marginal softening during deformation at 773 K. The microstructure evolution in both the deformed specimens reveals the prevalence of dynamic recrystallization (DRX) via continuous dynamic recrystallization (CDRX) and discontinuous dynamic recrystallization (DDRX) mechanisms which resulted in flow softening. VPSC simulation reveals that the activation of non-octahedral (NOC) slip systems ({100}<110> and {110}<110>) in conjunction with octahedral (OC) slip system ({111}<110>) predicts the microtexture evolution accurately for both the deformation conditions. The higher fraction of DRX, higher activation of NOC slip systems and grain boundary sliding contributed towards reducing texture intensity, and significantly improving the ductility at 773 K.

Keywords: Al-Li alloy; Deformation behaviour; Dynamic recrystallization; Finite element; Formability; Grain boundary sliding; Microtexture; Single point incremental forming; Strain; Strain path; Stretch forming; Taylor factor; Velocity gradient; VPSC simulation.